Coordination in plants

Plants do not possess nervous system and depend entirely on chemical coordination. Their responses are slower and they often involve growth. Growth in turn, can result in movement of an organ. Plants are coordinated by chemicals which have their effect on some aspects of growth, they are called growth substances. As some of these chemicals stimulate plant growth while some others retard the rate of growth, these chemicals are also referred to as plant growth regulators. Growth regulators include growth promoters (Auxins, gibberellins, cytokinins) as well as growth inhibitors (Abscisic acid). These are essential for the balanced and controlled development of plants. These are commonly known as auxins, cytokinins, gibberellins, abscissic acid and ethylene. These are also called phytohormones.

Plant hormones

Plant hormones are defined as the organic substances which are synthesized in minute quantities in any part of the plant and transported to another part where they are active. There are five main types of naturally occurring hormones. They are:

1. Auxins
2. Gibberellins
3. Cytokinins
4. Ethylene
5. Abscicic acid (ABA).

I. Auxin: The most common natural auxin is indole 3-acetic acid or IAA.

Discovery: - It was isolated for the first time by a Dutch botanist F.W. Went in 1928. The name Auxin was given by Went and he concluded no growth can occur without auxin.

Functions:

1. It promotes cell enlargement and cell differentiation in plants.
2. It is essential for the root formation on stem cuttings.
3. It suppresses the growth of lateral buds.
4. It promotes flowering in certain plants such as pine apple but delays it in lettuce.
5. Auxins are found to initiate many physiological processes, like protein synthesis, water uptake, respiration, seed germination.
6. It promotes fruit growth.
7. It prevents premature falling of leaves & fruits.
8. Auxins induce parthenocarpy in a number of plants.

Auxins are present in root and shoot apices.

II. Gibberellin: - They occur in roots, stem, leaves, flower buds, fruits and immature seeds.

Discovery: Gibberellins were discovered in 1926 by E. Kurosawa, a Japanese plant pathologist. Kurosawa while working in the rice fields observed that rice seedlings grew much taller than the others such plants were found to be infected by a fungus Gibberella fujikuroi. The disease was known as 'Bakanae disease' Yabuta and Sumiki (1938) demonstrated that some substance secreted by the fungus was probably responsible for enlongation growth of the seedlings. They isolated this substance from Gibberella fujikuraoi and named it Gibberellic acid.

Functions:-

i. G.ibberellin causes the elongation of stem and leaf sheaths.
ii. Gibberellic acid stimulates cell division.
iii. It helps in breaking the dormancy in seeds and buds.
iv. It also promotes fruit growth.
v. It includes parthenocarpy in many plants e.g. tomato.

Cytokinins: - They are synthesized in root tips from where they reach shoots.

Discovery: Miller and Skoog in 1955 discovered a substance which was known to activate cell division. They named this compound as kinetin. The first natural cytokinin was zeatin.

Functions:

i) The most important function of cytokinins the promotion of cell division.
ii) Cytokinins along with auxins are required for the growth of cellular in tissue culture experiment.
iii) It promotes cell enlargement.
iv) It can break seed dormancy and also promote seed germination.
v) Application of cytokinins delays the phenomenon of senescence or ageing.
vi) It provides resistance to plants against very high and low temperature from injuries.
vii) In some cases cytokinins have been found to induce flowering.
viii) It enhances chlorophyll development and the rate of synthesis of chlorophyll.
ix) They over come apical dominance and allow sprouting of lateral buds.
x) It regulates phloem transport.

Ethylene: - Ethylene is present as a volatile gas in atmosphere. It is produced in all living tissues of plants. It moves through diffusion process.

Discovery:-Denny (1924) observed that ethylene gas was highly effective in inducing fruit ripening. Zimmerman et al (1931) found that it induces fruit ripening. Later on physiological studies led to discovery of ethylene as a natural product of fruit ripening.

Functions:-

1. It has inhibitory effect on growth.
2. It promotes transverse or is diametric growth and inhibits longitudinal growth.
3. It induces senescence or ageing.
4. It induces yellowish of leaves.
5. It induces flowering in some plants like pine apple.
6. Ethylene stimulates abscission of various plant parts.
7. It suppresses bud growth.
8. It induces ripening in fruit.
9. It induces epinasity. (downward bending of leaves)
10. It induces germination in some species.
11. It induces root their formation.

Abscisic acid– (ABA):- ABA are thought to be formed in leaves and then transported to apices through phloem. These work as growth inhibitors.

Discovery:-Corn and Addicot (1963) while working on shedding of cotton balls found that a chemical substance abcisin II is responsible for their shedding. This substance was named as Abscisic acid (ABA).

Functions:

1. It has inhibitory effect on growth.
2. It promotes senescence or ageing.
3. It promotes abscission or falling of leaves, fruits & flowers of plants.
4. It favours stomatal closure.
5. ABA plays an important role in plants during water stress and during drought conditions.
6. It is known to inhibit the process of flowering, fruit and seed development.

Plant Movement:-

These are the changes in orientation of some plant parts in relation to others caused by intrinsic (internal) or extrinsic (external) stimuli.

There are two types of movements shown by plants:
Growth movements (tropic movements or tropism) and
Non Growth movements (nastic movements)

Types of movements in plants

The movements in plants due to external stimuli are of two types:

i. Tropic movements
ii. Nastic movements

Tropic movements:- These are induced growth movements that occur due to differential growth. These are the unidirectional movement of plants in response to external stimuli such as light, force of gravity, chemicals, water, are called tropic movements. The movements are either towards or away from the stimuli. These movements are slow. The phenomenon of such movements is called as tropism. Depending upon the nature of external stimulus the tropic movements are of following types:

i. **Geotropism:-** The movement of a plant in response to the force of gravity is called geotropism or geotropic movement. Different parts of a plant respond differently to the stimulus of gravity. Primary root always moves in downward direction. This is known as positive geotropism. The shoot moves upwards just opposite to the force of gravity. Hence the stem of a plant shows negative geotropism.

ii. **Phototropism:-** The movement of plant organs in response to the effect of light is known as phototropism. In simple words the response of a plant to the light is called phototropism. When some parts of a plant for example stem moves towards the light it is called positive phototropism, on the other hand when some organs for example, roots move away from the light it is called negative phototropism.

iii. **Hydrotropism**:- The movement of plant parts in response to the effect of water stimulus is known as hydrotropism. In simple words the response of a plant part to water is called hydrotropism. If some parts of a plant move towards the water it is called positive hydrotropism. While if some plant parts move away from the water it is called negative hydrotropism. Roots are positively hydrotropic as they bend towards the source of water. Sporangiophores of many moulds grow away from moist substratum, there by showing negative hydrotropism.

iv. **Chemotropism**:- The movement of a plant part in response to the stimulus of a chemicals is called chemotropism. But if the plant moves towards the chemical stimulus, it is called positive Chemotropism. But if the plant moves away from the chemical stimulus it is called negative chemotropism. The growth of pollen tube through the style towards the embryo sac is the example of positive chemotropism. Roots grow away from harmful acids there by showing negative chemotropism.

Nastic movement

Nastic movements are non directional induced movements that occur due to turgor changes in the cells. Such movements are due to the stimulus of light, temperature or contact but the direction of response is determined by the direction of stimuli. However, from whichever direction the stimulus is applied, it affects all the parts of the organs of a plant equally and they always move in the same direction. They reveal immediate response to stimulus but do not involve growth.

Nastic movements are of the following two types:

i) Seismonastic movement ii) Nyctinastic movement

i) **Seismonastic movement:-** These are the movements which occur in response to touch. The best example of seismonastic movement is the movement of the leaves of the sensitive touch me not plant Mimosa pudica. Leaves of touch me not plant droops rapidly when touched. It is due to turgidity of cells at the base. Here touch response is diffused affecting the entire leaf. Thus, the leaf droops down due to loss of turgor pressure. After sometime, the leaves regain their original shape. This phenomenon is also commonly called as thigmonasty.

ii. **Nyctinastic movement or Sleep movements: -** The diurnal (change in day and night) movements of leaves and flowers of some species in day and night are called nyctinastic movements. Since these movements occur in response to day and night, they are also known as sleep movements. These are movements due to turgor change in cells. Depending upon the stimulus they may be photonastic or thermonastic movements.

When the movement is induced by the change in light intensity, it is called photonastic movement e.g. dandelion flower. It opens in the morning in bright light and closes in the evening when the light fades.

The movement due to change in temperature, is called thermonastic movement. The flower of tulips (Tulipa) and Crocus show thermonastic movements.

Photoperiodism and flowering.

The length of the day (in hours) during which sunlight is available to the plants is called photoperiod. The effect of photoperiod on the germination of seeds and flowering in plants is called photoperiodism.

Photoperiod acts as a stimulus for plants. Plants respond to this stimulus with the help of a special kind of pigment present in them in very small amounts. The special pigment is called phytochrome which is a blue green pigment.

Garner and Allard in 1920 recognized three classes of plants according to their photoperiodic responses.

i) Short day plants ii) Long day plants and iii) Day neutral plants

i) **Short day Plants:-** A short day plant is one that flowers on photoperiods shorter than the critical day length e.g. tobacco plant.

ii) **Long Day Plants:-** A long day plant is one that flowers on photoperiods longer than critical day length e.g. wheat plants.

iii) **Day Neutral Plants:-** These plants do not require specific photoperiods to flower e.g. cucumber, maize, etc.

Coordination In Animals:

Evolution of multicellularity in animals necessitated the development of some system for the control and coordination of the activities of various cells of the body. Such a control and coordination, in fact, requires

i) Gathering information about changes in the external environment,

ii) Transmitting this information to the internal cells located away from the body surface, and

iii) Exchange of information between the cells situated away from each other.

In lower multicellular animals, the coordination takes place through the nervous system. However, in higher animals, coordination takes place through two types of control systems: nervous system and endocrine system.

1. **Nervous System:-** The nervous system is composed of specialized cells called neuron (nerve cells) which exercise control by sending electrical signals called

nerve impulses. The nervous control is speedy and flexible but its effect is localized.

2. **Endocrine System**:-The endocrine system consists of specialized glands (endocrine glands) which bring about control by sending chemical messengers termed hormones. The hormonal control is usually slow acting and its effect is diffuse.

Nervous System In Animals: Except sponges, all multicellular animals possess simple or complex nervous system. In all these animals, nervous system is comprised of nervous tissue having specialized cells called neurons or nerve cells to respond to stimuli and coordinate animal's activities.

Nerve cells or neurons are, in fact, the structural and functional units of nervous system. In higher multicellular animals, the nervous tissue consists of nerve cells of neurons, nerve fibres, bundle of nerve fibres forming nerves, packing cells (neuroglia), ependymal cells and neurosecretory cells.

Arrangement Of Neurons

The neurons lie end-to-end in chains to transmit nerve impulses in the animal body. Each neuron receives an impulse through its dendrites and passes it on to to the next neuron in the chain through its axon via cell body.

Synapse: The neurons are not connected. There occurs a very minute gap between terminal portion of axon of one neuron and the Dendron of other neuron. This minute gap is called synapse. Synapse is thus the functional junction between neurons. At the synapse, axon terminal comes in close proximity to the dendron terminal of next neuron. Axon terminal is expanded to from presynaptic knob. On the other hand, the dendrite terminal forms post-synaptic depression. In between the two, lies a narrow fluid filled space called synaptic cleft.

As the nerve impulse reaches the presynaptic knob, the synaptic vesicles get stimulated to release a chemical called neurotransmitter in the synaptic cleft. The neurotransmitter molecules diffuse across the gap (synapse) to come in contact with the chemoreceptor sites in the post-synaptic membrane. In this way, nerve impulse passes across the minute gap (synapse) to stimulate dendron of other neuron.

The synapse acts as a one-way valve to conduct nerve impulse in one direction only. This is so because chemical substance, called neurotransmitter, is secreted by synaptic vesicles only on one side of the gap, i.e. on axon's side. The neurotransmitter carries message across the synapse and passes it to the dendron of the other neuron.

In this way, impulses travel across the neurons only in one direction, i.e. from axon of one neuron to dendron of other neuron through a synapse.

Define:-

Nerve Impulse:-

It is a self propagated electrochemical current that travels from one neuron to another neuron for the passage of message.

Receptor:- It is a nerve cell or group of nerve cells which is sensitive to a specific stimulus or to specific change in the environment.

Effector:- It is a muscle or gland in specific part of the body which produces suitable response.

Types Of Neurons

The neurons are of three types:

i) Sensory (receptor) neurons, ii) motor (effector) neurons and (iii) relaying (connector) neurons.

i) **Sensory (Receptor) Neurons:-** These often occur in sense organs and receive stimuli by their dendrites. The sensory neurons transmit impulses towards the central nervous system (brain and spinal cord) through their axons.

ii) **Motor (Effector) Neurons:-** The dendrites of these neurons synapse with axons of sensory neurons in central nervous system. They transmit impulses from central nervous system towards effectors (muscles or glands). The latter respond to stimuli.

iii) **Relaying (connector) Neurons:** Thse occur in the central nervous system (brain and spinal cord). These serve as links between sensory and motor neurons for distant transmission of nerve impulses.

Sensory Receptors:-

It is a cell or group of cells specialized to detect a particular stimulus and to initiate the transmission of impulses via. The sensory nerves.

There are five receptors or sense organs through whicvh the animals receive stimuli or external informations. These receptors are phonoreceptors for sound (ears), gustatory receptors for taste (tongue), olfactoreceptors for smell (nose) and thigmoreceptors for touch (skin). The receptors pass information to the brain. The brain transmits motor impulses to appropriate effectors which produce suitable responses.

Structure of neuron:

Neuron is the structural and functional unit of nervous system. It has a special structure to receive, conduct and transmit impulses. It varies greatly in shape and size. A neuron consists of three prominent parts: i)Cell body ii) Dendrites iii) Axon

i) **Cell body:-** The cell body of a neuron is called as cyton or soma. This cyton is broad, rounded, pyriform or stellate part of neuron. It has abundant cytoplasm called neuroplasm and a relatively large, speherical nucleus. The cytoplasm has mitochondria, golgi apparatus, neurofibrils, neurotubules and special granules called Nissl's granules or Tigroid body. Nissl granules were discovered by a German neurologist Franz Nissl. They are formed by the combination of ribosomes with rough endoplasmic reticulum and are meant for the synthesis of neurotransmitter (acetyl choline)

   Centrioles are absent in neurons. Cell body is concerned with metabolic maintenance and growth. It also receives nerve impulses from dendrites and transmits them to axam.

ii) **Dendrites (singular Dendron):-** These are several short, tapering, much branched protoplasmic processes stretching out from the cell body of a neuron. Dendrites are the part of neuron where sensation is acquired. The information then travels as an electric impulse towards the cell body. Dendrites contain Nissl's granules and neurofibrils.

iii) **Axon:-** It is single, long, cylindrical protoplasmic process of uniform diameter arising from cell body. At its terminal end, it is highly branched and the terminal branches are called terminal arborization. At the ends of terminal arborization, are swollen structures called synaptic knobs that have a neurotransmitter called acetyl choline in them. Acytyl choline diffuses out at the time of conduction of nerve impulse.

Axon is covered with one or two sheaths. Sheathed axon is termed as nerve fibre. The cell membrane of the axon is called axolemma and its cytoplasm is termed axoplasm. It lacks Nissl's granules. However, neurofibrils are present. The single sheath present over the axon is made of Schwann cells and is called neurilemma. The axon may have an additional insulating and protective sheath of myelin around it. It is present between neurilemma and axon. Axons having myelin sheath are termed myelinated fibres and those without this sheath are termed non myelinated nerve fibres. At intervals, myelinated nerve fibres possess unmyelinated areas called nodes of Ranvier.

Characteristics of neurons:

i) They do not divide.
ii) They are formed shortly after birth.
iii) They are not repaired, when injured.
iv) They use only glucose as a respiratory substrate.
v) They die, if deprived of oxygen for over 5 minutes.

Functions of neurons:

The information acquired at the end of the dendritic tip of a neuron sets off a chemical reaction which creates an electrical impulse. The impulse travels from the dendrite along the axon of its end. At the end of axon, the electrical impulse sets off the release of some chemical, which cross the synapse and start a similar impulse in the dendrite of next neuron. In this way, nerve impulses travel in the body. Thus, nervous tissue is made up of an organized network of neurons which are specialized for conducting information via electrical impulse from one part of body to another.

Reflex Actions, Involuntary And Voluntary Actions

Animals perform three types of actions. These actions are:

- Reflex actions.
- Involuntary actions.
- Voluntary actions

Reflex actions:- Reflex action was discovered by Marshal Hall (1833). A reflex action may be defined as a spontaneous, unconscious automatic and mechanical response to a stimulus, acting on a specific receptor, without the will of an animal.

Need for Reflex Action:- The receptors, present on various body parts, receive stimuli and transmit information in the form of nerve impulses to the central nervous system which has various coordination centres where the information is processed. The processing is done on the basis of information and experiences already stored. The message is then sent by coordination centres through motor neurons to appropriate regions of the body which accordingly respond and react. The whole process takes some

time. However in certain situations, sensation requires immediate response as time used for processing may cause harm to the body. In such situations, reflex actions occur.

Examples. Blinking of eyes, movement of diaphragm during respiration, coughing, yawning, sneezing etc.

What Happens in Reflex Actions?

In reflex action, fine tips (dendrites) of receptors (sensory neurons) quickly relay a message (electric impulse) via sensory nerves to the spinal cord. The spinal cord then sends information (impulse) via motor nerves to effectors (muscles or glands) which show response. The path taken by nerve impulses in a reflex action is called reflex arc.

Reflex Arc: The path taken by nerve impulse in a reflex action is called reflex arc. It consists of five parts:

i) **Receptor**: It is a specific group of cells or organ, the neurons of which receives a stimulus and set up a sensory impulse.

ii) **Sensory (Afferent) Nerve:-** It carries sensory impulse from the receptor to the central nervous system.

iii) **A Portion of Central Nervous System:-** It is spinal cord or brain. Its neurons analyse and interpret the sensory impulse and set up an appropriate motor impulse. Accordingly, reflexes are termed spinal reflexes or cerebral reflexes.

iv) **Motor (efferent) Nerve:-** It carries motor impulse from the central nervous system to specific effectors (muscle fibres or gland cells).

v) **Effector:** It may be muscle fibres or gland cells. Here, impulse terminates and response occurs as per instructions received from central nervous system.

For example when our hand accidently touches a hot object, the heat is sensed by thermo receptors present in the skin of hand. The stimulus triggers nerve impulse in sensory (receptor) neuron. It transmits message to the spinal cord. In the spinal cord, impulse is passed on to the relay (connector) neuron which, in turn, passes it to the motor neuron. The motor neuron transmits the instruction to a muscle in our arm. The arm muscle contracts and pulls our hand away from the hot object. Such reflexes which involve spinal cord are also termed spinal reflexes.

Significance of Reflex Action

1. It checks overloading and overtaxing of brain.
2. It results in quick response to otherwise harmful stimuli without the processing done by coordinating centres of central nervous system.
3. It has survival value.

Involuntary Actions

Involuntary muscular actions are performed by the animal without its will. These occur automatically and the animal has no choice in it. Such actions are meant for controlling and coordinating the functioning of internal organs. Many of these involuntary actions are controlled by the midbrain and hind brain. Regular breathing of heart, blood pressure, movements of diaphragm during normal respiration, peristaltic movements in the oesophagus, salivation, vomiting, movement of the internal viscera etc. are all involuntary actions and are controlled by hind brain.

Voluntary Actions

Voluntary muscular actions are performed by the animal with its will. In each voluntary action, the animal exercises its choice so that the same stimulus may receive different responses at different times depending upon the situation. For instance, on seeing a snake in the way, one may run away on first occasion or call for help on second occasion or try to kill it to save himself on the third occasion. All such actions are voluntary actions that are controlled by cerebellum part of hind brain. Similarly, walking in a straight line, riding a bicycle, picking up a pencil are also voluntary actions controlled by cerebellum.

How Does the Nervous Tissue Cause Action?

The terminal part of axon of motor neuron synapses with the membrane of the muscle (motor end plate). When the nerve impulse from CNS reaches the muscle, the muscle fibres show movement. The muscle fibres, in fact, have special proteins that change their shape and their arrangement in response to nerve impulses. New arrangement of these proteins gives the muscle different shapes.

Human Nervous System

Human nervous system is the most complex. It is divided into two main parts:

i) Central nervous system
ii) Peripheral nervous system

i) **Central Nervous System (CNS):-** It is hollow and lies on the mid dorsal part along the main (longitudinal) axis of the body. It is covered externally by part of axial skeleton. The CNS, in turn, consists of two parts:
   a) Brain or encephalon situated in the head.
   b) Spinal cord or myelon located in the neck and trunk.

a) **Brain (Encephalon):-** The brain is the widest and the uppermost part of the central nervous system. It is the highest coordinating centre in the body. Brain is situated in the cranial cavity of the skull in the head region of the body. The bones of cranium or brain box protect this delicate organ from mechanical injury. The brain is contained in a fluid-filled balloon which provides further shock absorption. The study of brain in all aspects is called encephalogy.

Morphology:-

The brain is soft, whitish organ. It weighs 1.2–1.4kg and forms about 98% of the weight of the whole central nervous system. It has about 100 billion neurons (nerve cells). Brain is surrounded by three membranes called meninges which provide protection to it. The space between these three meninges is filled with cerebro-spinal fluid which protects the brain from mechanical shocks. The cell body of the neurons constitutes the grey matter and the fibres constitute the white matter of brain. Both the brain and spinal cord have white matter (bundles of axons having myelin sheaths) and grey matter (masses of the cell bodies and dendrites).

Brain is divisible into three main regions:

1. Forebrain
2. Midbrain, and
3. Hind brain

1. **Forebrain (Prosencephalon):-** It forms the greater part of the brain. It further consists of three regions: olfactory lobes, cerebral hemispheres (cerebrum) and diencephalon.
   i) **Olfactory lobes:** - These are a pair of widely separated club-shaped small structures. These are fully covered by the cerebral hemispheres and are, thus, visible only in the ventral view of the brain. Each olfactory lobe consists of an anterior olfactory bulb and a posterior narrow olfactory stalk. These lobes receive impulses from olfactoreceptors (present in the olfactory epithelium in the nose) and relay sense of smell to the temporal region of the cerebrum.
   ii) **Cerebral hemispheres (cerebrum):- It** forms the largest part of the brain. It is also the most complex and specialized part of the brain. The two cerebral hemispheres lie side by side, being separated from each other by a deep longitudinal cerebral fissure. The surface of these cerebral hemispheres is greatly folded to accommodate large number of nerve cells. The folds are called gyri (singular gyrus) and the depressions between them are termed sulci (singular sulcus). Each cerebral hemisphere is divided by three deep fissures into four lobes: anterior frontal lobe, middle parietal lobe, posterior occipital lobe and lateral temporal lobe. Different areas of cerebrum have different functions. For instance, it has sensory areas which receive impulses from the sense organs or sensory receptors, e.g. eyes, ears, tongue, nose and skin. Similarly, cerebrum also has motor areas which send instructions in the form of impulses to various effectors of the body (e.g. muscles). The latter then respond to stimuli. There are specific regions in cerebrum for each kind of stimulus and its response. For instance-
      - Frontal lobe is the region of speech, facial muscular activities as well as higher mental activities.
      - Temporal lobe is the region for auditory reception (hearing).
      - Occipital lobe is the region for visual reception (sight).
      - Parietal lobe is the region for touch, taste, smell, temperature and conscious association.

      Each lobe also has some areas called association areas which store information and experiences. These association areas control thinking, memory, learning and emotions. Internally, each cerebral hemisphere possesses a fluid-filled cavity called lateral ventricle.
   iii) **Diencephalon:-** It lies on the inferior side of the cerebrum and thus is visible in the ventral view of the brain. Its roof is called epithalamus, sides are called thalami and its floor is termed hypothalamus, Diencephalon has a narrow cavity called third ventricle. Hypophysis (pituitary) is attached by a stalk or infundibulum to the hypothalamus region. Hypothalamus has control centres for hunger, thirst, fatigue, sleep, body temperature, sweating and emotions. It secretes neurohormones which regulate the secretions of pituitary.
2. **Mid brain (Mesencephalon):-** It is significantly small region. It consists of two fibre tracts called crura cerebri and two swellings called superior and inferior colliculi on each side. The fibrous tracts, i.e., crura cerebri connect hind brain with the fore brain. The four swellings of both sides are together known as corpora quadrigemina. The

two superior colliculi have centres for sight reflexes while the two inferior colliculi have centres for auditory reflexes.

The mid brain controls reflex movements of:

i) The head, neck and trunk in response to visual and auditory stimuli, and

ii) The eye muscles; changes in pupil size as well as shape of the eye lens.

3. **Hind brain (Rhombencephalon):-** The hind brain consists of three parts:- cerebellum, pons varolii and medulla oblongata. The cerebellum is the second largest part of the brain, constituting nearly 12.5% of it. It has two large, lateral cerebellar hemispheres and a central vermis. Cerebellum maintains the posture, equilibrium and muscle tone. Pons varolii controls some aspects of respiration. Medulla oblongata is the posterior most part of the brain which lies below the cerebellum. It continues posteriorly into the spinal cord. It contains a fluid-filled cavity called fourth ventricle. Medulla oblongata controls (i) rate of heart beat, (ii) breathing movements, (iii) expansion and contraction of blood vessels to regulate blood pressure, and (iv) swallowing, coughing, sneezing and vomiting.

Twelve pairs of cranial nerves arise from the brain.

Functions of brain:

i) It receives information by carrying impulses from all the sensory organs of the body.

ii) It response to the impulses brought in by sensory organs by sending its own instructions to the muscles and glands causing them to function accordingly.

iii) It correlates the various stimuli from different sense organs and produces the most appropriate and intelligent response.

iv) It coordinates the bodily activites so that the mechanisms and chemical reactions of the body work together efficiently.

v) It stores information so that behavior can be modified according to the past experience. This function makes the brain the organ of thought and intelligence.

2. **Spinal Cord:** Spinal cord is a cylindrical structure and is about 45cm long. It begins in continuation with the medulla oblongata of brain and extends downwards upto early part of lumber region. It then extends to the end of vertebral column as fibrous connective called filum terminale. Internally, the spinal cord possesses a narrow, fluid-filled cavity called central canal. Spinal cord is enclosed in the vertebral column or backbone which protects it. Like brain, spinal cord too is surrounded by meninges. Thirty one pairs of spinal nerves arise form the spinal cord. Spinal cord performs two important functions:

i) It conducts sensory and motor impulses to and from the brain.

ii) It acts as a centre for the reflex actions. Thus, it reduces brain's work.

Peripheral Nervous System

It connects CNS with different parts of the body. It has two components, voluntary and involuntary.

Voluntary peripheral nervous system is under the control of will. It consists of nerves that arise directly from CNS connecting different body parts for voluntary (conscious) control of the brain.

Involuntary peripheral nervous system (autonomic nervous system), on the other hand, is not under the control of human will. It develops from branches of some cranial and spinal nerves called visceral nerves.

Peripheral nervous system, thus, consists of all the three types of nerves namely,

i) Cranial nerves ii) Spinal nerves (iii) Visceral nerves

i) **Cranial nerves:-** Cranial nerves arise from the brain and spread to various parts of the head. They are 12 pairs in number. Cranial nerves I, II and VIII are sensory nerves; cranial nerves III, IV, VI, XI and XII are motor nerves; and cranial nerves V,VII, IX and X are mixed nerves (containing both sensory and motor nerve fibres).

ii) **Spinal nerves**:- Thirty one pairs of spinal nerves arise from the spnal cord along most of its length and spread throughout the body (except head region). They are all mixed nerves as they carry both sensory and motor nerve fibres.

iii) **Visceral nerves:-** Apart from regulating normal functions of the body, many activities of the internal organs such as heart, kidney, lungs , urinary bladder, blood vessels, glands etc. are controlled by specific set of nerves called visceral nerves which mostly arise from spinal cord but a few from the brain also. These form the autonomic nervous system.

Autonomic Nervous System:

It is the system which operates automatically or involuntary. It includes of those responses against stimuli which are not under the control of animal. Visceral nerves of autonomic nervous system control the activities of internal organs. So it is also termed as visceral nervous system.

Autonomic nervous system is subdivided into two parts:

i) Sympathetic nervous system ii) Parasympathetic nervous system

Protective coverings:

Both brain and spinal cord are protected from mechanic injury and shock by bony cases around them. Brain is protected by cranium (brain box) while spinal cord is protected by vertebral column. There are also present additional protective coverings called meninges between the brian or spinal cord and their respective bony cases. These meninges are three in number namely duramater, piamater and arachnoid. The space between the meninges is filled by a fluid called cerebrospinal fluid

Cerebrospinal fluid:-

it is a clear , colourless slightly alkaline fluid present in the ventricles of the brain, spinal cord and spaces between meninges. It protects the CNS from shocks and keeps its moist. It also carries wastes, drugs and other harmful substances from brain to the blood. It also maintains a constant pressure inside the cranium inspite of variations in the pressure of blood in the cranial vessels.

Chemical Coordination In Animals

In animals, the message, communicated in the form of nerve impulses, from receptors (sensory neurons) to central nervous system and from latter to the effectors (muscles and glands) is very quick. The nervous coordination in animals, however, has certain limitations. For instance,

- Nerve impulses can reach to only those animal cells which are connected by nervous tissue, and
- Such cells, after generation and transmission of nerve impulses, take some time to reset their mechanisms before a new impulse is generated and transmitted.

Hormones

The word hormone was introduced by William M. Bayles and Earniest N. Starling. It has been derived from the Greek work harmein which means to excite because it is responsible for excitement or disturbance in our body. These are secreted by special cells called endocrine cells. Hormones, therefore, are chemical substances secreted in trace amounts by endocrine glands and are means of information transmission.

Transport And Recognition Of Hormones

The cells of endocrine glands secrete chemical substances. When they receives stimulus they pour these secretions in blood which then goes to each and every organ but only target organ shows response because in target organ special sites called receptors are present and a particular hormone gets binded with it and the message present in hormones gets transmitted to receptor. The shape of receptor gets changed because it receives new information due to which new responses get produced.

Difference between nervous and hormonal information

	Nervous information	**Hormonal information**
1	It is sent as an electrical impulse along axons, and as a chemical across synapse.	It is sent as a chemical messenger via blood stream.
2	Information travels rapidly, in milliseconds.	Information travels slowly.
3	Information is directed to specific receptors-one of a few nerve fibres, gland cells or other neurons, i.e., it is addressed by name.	Information is spread throughout the body by blood from which the target cells or organs pick it up, i.e., it is addressed to 'whom it may concern'.
4	It gets response immediately.	It gets response usually slowly.
5	Its effects are short-lived.	Its effects are generally more prolonged.

Characteristics of hormones

The hormones in animals show following characteristic features:

i) They are synthesized by endocrine glands.

ii) They are produced at a place other than the site of action. They travel through blood to other parts where they cause changes.

iii) They are secreted directly into the blood stream.

iv) They act on specific tissues or organs. The tissues or organs that respond to the hormones are called as target organs.

v) They are secreted in response to changes in the external or the internal environment of the body and are also called as chemical messengers.

vi) They may stimulate or inhibit the activity of the target organ, thus regulating its activity.

vii) They are effective in minute quantities, often in trace amounts difficult to detect at times.

viii) Excess or deficiency of a hormone may lead to serious consequences.

Glands and its types:

Gland: It can be the cell or tissue or organ which secretes certain useful substances for the proper functioning of body.

There are three types of glands in animals.

i) **Exocrine glands:-** These are those glands which directly pour the secretions into the duct and these ducts carry them to target organs. These are also called duct glands for example salivary glands, gastric glands, etc.

ii) **Endocrine glands:-** It has been derived from Greek word 'endon' which means within and 'Krinein' which means to secrete. These are those glands which directly pour their secretions into blood and are called ductless glands or are also known as glands of internal secretion. There secretions of endocrine glands are called hormones or internal secretion for example pituitary glands, thyroid glands, parathyroid gland etc.

iii) **Heterocrine glands:-** These glands consist of both exocrine and endocrine glands. A part of Heterocrine gland act as exocrine gland and a part of it acts as endocrine gland. For example pancreas and gonads. A part of pancreas acts as endocrine gland and secretes insulin and glycogen and a part of it acts as exocrine gland and secretes pancreatic juice. Another example is of ovaries in females. Its endocrine part secretes estrogen and progesterone and its exocrine part produces ova. Another example is testes in males. Its endocrine part secretes testosterone and its exocrine part produces sperms.

Human endocrine glands

The major endocrine glands, their secretions, principal functions of the various hormones secreted by them are:-

1. Hypothalamus :- It is situated at the base of the brain and is composed of nervous tissue. The neurosecretary cells of the hypothalamus secrete several neurohormones called Releasing Hormones (RH) and Inhibiting Factors or Hormones (IF or IH). These neurohormones are carried to the pituitary gland to stimulate or inhibit the secretion of anterior pituitary hormones. Hypothalamus also secrets two neurohormones oxytocin and vasopressin (also called antidiuretic hormone or ADH). These are subsequently stored in posterior lobe of pituitary.

2. **Pituitary gland:-** It is small, red, grey in colour and is pea shaped and pea sized. It is located below brain and is attached to hypothalamus by means of stalk called infundibulum. It has three lobes:-

a. **Anterior lobe:-** It produces six hormones.

i) Growth hormone (GH) or Somatotrophic hormone (STH)

Functions:

It controls the overall development or growth of body, muscles, bones and tissues.

ii) Thyroid stimulated hormone (TSH):-

Functions:

It controls the growth and functioning of thyroid gland. It also stimulates the thyroid gland to produce thyroxine.

iii) Adrenocorticotrophic hormone (ACTH)

Functions:

It stimulates the adrenal cortex to secrete its hormones.

iv) Follicle stimulating hormone (FSH)

Functions:

In males, it stimulates the process of spermatogenesis (sperm formation). In females, it stimulates the follicle cells in the ovaries to develop into mature eggs and also stimulates them to produce oestrogen.

v) Luteinising hormone (LH) (FSH and LH are together called gonadotrophins)

Functions:

In males, it stimulates the secretion of male hormone, testosterone (sex hormone in males). In females, it stimulates the secretion of oestrogen and progresterone (sex hormones in females).

vi) Prolactin hormone (PRL)

Functions:

It enhances mammary glands development and milk production in females.

b. Intermediate lobe: It secretes melanocyte stimulating hormone (MSH)

Functions:

It stimulates the synthesis of melanin in the skin.

c. Posterior lobe: It secretes

i) Oxytocin

Functions:

It stimulates contraction of smooth muscles at the time of child birth. It also helps in milk ejection (lactation) from the mammary glands.

ii) Vasopressin or Antidiuretic hormone (ADH)

Functions:

It regulates water and electrolyte balance in body fluids.

3. Pineal gland:- It lies between the two cerebral hemispheres of the brain. It secretes melatonin.

Functions:

It regulates the working of gonads.

4. Thyroid gland

- It is situated in the neck region on the ventral side of the body. It has two lateral lobes, one on either side of the trachea.

a) Thyroxine or T4 and tri iodothyronine or T3.

Functions:

T3 and T4 stimulates the rate of cellular oxidation and metabolism.

b) Calcitonin:-

Functions:

Calcitonin lowers calcium level when by suppressing release of calcium ions from the bones, calcium level is high in blood.

5. Parathyroid gland:

- These are four small oval bodies which lie embedded in the lobes of the thyroid gland. It secretes parathyroid hormone (PTH) or parathormone.

Functions:

It regulates calcium and phosphate levels in the blood. When blood calcium level is below normal, it mobilizes the release of calcium into the blood from bones. It has an action opposite to that of calcitonin on calcium metabolism.

6. Thymus gland:

- It is situated in the upper chest near the frond side of heart.. It secretes thymosin.

Function:

It stimulates the development and differentiation of lymphocytes.

7. **Adrenal gland:-** In human being, a pair of adrenal glands are present, one on top of each kidney, so are also called as suprarenals . Each adrenal gland has an outer part called the cortex and an inner part medulla.

i) Adrenal cortex: It secretes three groups of hormones.

- Glucocorticoids:- It regulates the metabolism of proteins, fats and carbohydrates in the body and the level of blood sugar. It regulates heart beat and blood pressure.
- Mineralocorticoids (Aldosterone):- It regulates water and mineral balance in the body.
- Sex corticoids:- It stimulates the development of secondary sexual characters both in males and females.

ii) Adernal Medulla :- It secretes two hormones.

- Adrenaline (Epinephrine) and Non-adrenaline (Non-epinephrine)

Functions:

Both these hormones together control emotions , fear, anger, blood pressure , heart beat, respiration and relaxation of smooth muscles.

8. **Pancreas:** It is a heterocrine gland and is located in the abdominal region. Its endocrine part is islets of langerhans which secretes two hormones.

- Insulin:- It regulates the conversion of glucose to glycogen i.e. it lowers blood glucose level.

- Glucagon:- It regulates the conversion of glycogen back to glucose i.e. it increases blood glucose level.

9. **Ovaries:-** These are the pair of organs present in lower abdominal region in females. It secretes two hormones:-
   - **Progesterone and estrogen:** - These play an important role in ovulation. These help in the preparation of uterus for the reception of fertilized ovum.
     These hormones also help in the maintenance of pregnancy.
     Oesotrogens are responsible for development of secondary sexual characteristics in females like mammary gland, voice, hair pattern, etc.

10. **Testes:** These are extra abdominal in position. The interstitial or Leydig cells present in testes produce male hormone. It secretes one hormone.

Testosterone:- It regulates the growth, development and functioning of accessory sex organs and controls the secondary sexual characteristics in males.

Disorders of endocrine gland

Disorders of pituitary

i) Dwarfism: Dwarfism is caused due to deficiency of growth hormone from early age.

ii) Gigantism:- It is giant size of the youngs with very tall skeleton and proportionally large muscles and viscera. It is caused due to excess secretion of growth hormone from childhood.

iii) Acromegaly: It is caused due to excess secretion of growth hormone after adolescence. Acromegaly in adults leads to overgrowth of the jaw bones and bowing of the spine (backbone)

iv) Diabetes insipidus: Deficiency of ADH reduces reabsorption of water and increases urine
output, causing excessive thirst. This disorder is called diabetes insipidus. No glucose is lost in the urine of such a patient.

Improper secretion of thyroid hormones

i) Grave's disease (exophthalmic goiter): It is caused by hypersecretion (oversecretion) of thyroid hormones due to enlargement of thyroid gland. Excess of thyroid hormones increases metabolic rate and accelerates oxidation. This results in quick consumption of food, leaving nothing for storage and causing emaciation (excessive leanness).

ii) **Simple goiter (iodine deficiency goiter or endemic goiter)**: It is the enlargement of thyroid gland accompanied with cretinism or myxoedema. Its caused due to dietry deficiency of iodine. This disease is common in hilly areas. It causes enlargement of thyroid gland. Swollen neck is one of the symptoms of this disorder. Addition of iodides to the table salt prevents the disorder. In our country, common salt is iodized to provide required iodine to the thyroid gland.

iii) **Myxoedema:-** It is caused by deficiency of thyroid hormones in adults. It is more common in women than in men.

iv) **Cretinism:-** Hypothyroidism (Hypo activity of thyroid gland) causes cretinism in young children. Its symptoms are stunted growth, short club-like fingers , deformed bones and teeth. Skin is rough, dry and wrinkled with scanty hair growth. Pot –bellied abdomen. Idiocy of varying degree is observed.

Deficiency of insulin:

Diabetes mellitus: Deficiency of insulin hormone in the body causing a disease known as diabetes mellitus. In this disease, the patient excretes sugar (glucose) in urine, feels excessive thirst and also does excessive urination.

Q How are involuntary action and reflex action different from each other?

Ans. Involuntary action:

i) Involuntary action involves autonomic nervous system.
ii) They occur in response to internal stimuli.
iii) They are connected with functioning of internal body parts.
iv) It occurs without the will of the organism. For example, heart beat, breathing, etc.
v) These are regulated by medulla oblongata (hind brain).

Reflex action

i) Reflex action involves all parts of voluntary nervous system though they are not voluntary.
ii) They operate against harmful stimuli which are generally external.
iii) Some reflexes involve the brain, rather than the spinal cord.
iv) Reflex is generally controlled by spinal cord.
v) They are connected with emergency i.e. response to stimuli.

Textual Questions

Q#1 What is the difference between a reflex action and walking?

Ans. Reflex action is a immediate response of the spinal cord to a sudden impulse. It is conducted by the spinal cord. But walking is a voluntary action which is controlled by cerebellum part of hind brain.

Q#2 What happens at the synapse between two neurons?

Ans. Synapse is the gap between the nerve endings of one neuron and dendrites of another neuron. At synapse, the electrical impulse generated at dendrites of a neuron is passed on the dendrite of another neuron in the form of chemicals by axon ending of the first neuron. Synapse also ensures that nerve impulse travels only in one direction.

Q#3 Which part of the brain maintains the posture and equilibrium of the body?

Ans. Cerebellum part of the hind brain maintain the posture and equilibrium of the body.

Q#4 How do we detect the smell of an agarbatti (incense stick)?

Ans. Smell of an incense stick is detected by the olfactory receptors located in the forebrain.

Q#5 What is the role of the brain in reflex action?

Ans. Reflex actions generally involve spinal cord for quick response to specific stimulus. However, the information input also goes on to reach the brain where thinking process occurs.

Q#6 What are plant hormones?

Ans. Refer to note on plant hormones.

Q#7 How is the movement of leaves of a sensitive plant different from the movement of the shoot towards light?

Ans. The movement of leaves of a sensitive plant is neither towards nor away from stimulus like touch. While movement of shoot is towards stimulus like light. The movement of leaves of sensitive plant is non directional while the movement of shoot is directional.

Q#8 Give an example of a plant hormone that promotes growth.

Ans. Auxin is the plant hormone that helps in cell elongation and growth.

Q#9 How do auxins promote the growth of a tendril around a support?

Ans. The movement of tendril around the support is caused by the auxins hormones. Less auxins occurs on the side of contact as compared to the free side. As a result, auxins promotes the growth on the free side and the tendril coils around the support.

Q#10 Design an experiment to demonstrate hydrotropism.

Ans. Experiment to Demonstrate Hydrotropism:

1) Take a wire mesh and cover it with moist saw dust.
2) Place some germinated seedling (pea or gram) on the moist saw dust.
3) Keep the saw dust moist by sprinkling water at regular intervals. Observe after 2-3 days.
4) As the radicals come out of seeds, they are seen to move towards the perforation. After some growth they bend back and enter the perforations to reach the moist saw dust in complete disregard of gravity (positive hydrotropism).

Q#11 How does chemical coordination take place in animals?

Ans. In animals chemical coordination is achieved through the agency of hormones which function as chemical messengers or informational molecules. Hormones are secreted in a very small amount by specialized tissues in the body called endocrine glands. In fact endocrine glands are often called ductless glands, because hormones are secreted directly into the blood without the involvement of any special duct. Hormones coordinate the activities of living organisms and also their growth. They affect only particular tissues called target tissues. These organs and tissues then responses and enabled the body to deal with different situations. For example, pancreas secretes two hormones, insulin and glucagon. The function of insulin hormone is to lower the blood glucose. Deficiency of insulin hormones in the body causes a disease known as diabetes. The function of glucagons hormone is to increase the blood glucose.

Q#12 Why is the use of iodised salt advised?

Ans. Iodine is essential for the synthesis of thyroxine hormone in the thyroid gland. Thyroxin regulates carbohydrates, protein and fat metabolism in the body so as to provide the best balance for growth.
In case of deficiency of iodine in our diet, there is a possibility that we suffer from goitre. Iodised salt contains proper content of iodine. Thus, to avoid deficiency of iodine, iodised salt is recommended.

Q#13 How does our body respond when adrenaline is secreted into the blood?

Ans. Adrenaline hormone is secreted in small amounts all the time, but in large amounts when a person is frightened or mentally disturbed. When adrenaline is secreted in large amounts it prepares our body for action. It increases the rate of heartbeat and breathing, raises blood pressure and allows more glucose to go into the blood to give us a lot of energy quickly to fight or runaway from the frightening situation or to deal with the emergency situations.

Q#14 Why are some patients of diabetes treated by giving infections of insulin?

Ans. Diabetes (Diabetes mellitus) is caused due to less or no secretion of hormone insulin by pancreas. In such a person, blood sugar level is high. Insulin converts extra sugar present in blood into glycogen. Thus, patients suffering from diabetes (Diabetes mellitus) are given insulin infections to control their blood sugar level.

Q#15 What is the function of receptors in our body? Think of situations where receptors do not work properly. What problems are likely to arise?

Ans. The receptors in our body collect information about changes in the environment around us in the form of stimuli, e.g., photoreceptors, gustoreceptors, thermoreceptors, statoreceptors, tangroreceptors. These

then pass the information in the form of nerve impulse to the central nervous system (spinal cord and / or brain) where the message is interpreted and appropriate instructions are sent to effectors (glands or muscles) which reveals responses. When receptors do not function normally, the environmental stimuli are not able to create nerve impulses and the body does not respond.

Q#16 Draw the structure of neuron and explain its function.

Ans. Refer to notes.

Q#17 How does phototropism occur in plants?

Ans. Photo tropism is a directional growth movement which occurs in response to unidirectional exposure to light. Phototropic movement is generally caused by increased ausin concentration on the dark side and less auxin concentration on the illuminated side. Due to the presence of more auxin, the part of the plant in the dark grows faster,causing it to bend towards the source of light.

Q#18 Which signals will get disrupted in case of spinal cord injury?

Ans. In case of spinal injury, reflex actions and involuntary actions will get disrupted.

Q#19 How does chemical coordination occur in plants?

Ans. In plants, chemical coordination occurs with the help of plant hormones (phytohormones). Amount of hormones depends upon the environment and other stimuli. Different plant hormones help to coordinate growth, development and responses to the environment. They are synthesized at places away from where they act and simply diffuse to the area of action, for example, auxin which promotes cell differentiation. Another example of plant hormones are gibberellins which help in the growth of the stem. Cytokinins promote cell division. Abscisic acid is a plant hormone which inhibits growth and its effects include wilting of leaves.

Q#20 What is the need for a system of control and coordination in an organism?

Ans. The body of a multicellular organism consists of a number of components and sub-components and each specialized to perform a particular function. Therefore, it is necessary that various organs of the body of an organism work together in a proper manner to produce proper response to a stimulus. In human being, nervous system and endocrine system work together for control and coordination.

Q#21 How are involuntary action and reflex action different from each other?

Ans.

Sr.No.	Involuntary Action	Reflex Action
1.	They involve autonomic nervous system.	They involve all parts of voluntary nervous system though they are not voluntary.
2.	They occur in response to internal stimuli.	They operate against harmful stimuli which are generally external.
3.	They are connected with functioning of the internal body parts.	They are connected with emergency.
4.	Involuntary actions occur without the will of the animal. For example, heartbeat, breathing, etc.	Some reflexes involve the brain, rather than the spinal cord.
5.	These are regulated by medulla for hind brain.	Reflex actions are generally controlled by spinal cord.

Q#22 Compare and contrast nervous and hormonal mechanism for control and coordination in animals.

Ans. Refer to notes.

Q#23 What is the difference between the manner in which movement takes place in a sensitive plant and the movement in our legs?

Ans. The differences between movement in a sensitive plant and the movement in our legs are:

Movement in a sensitive plant	Movement in legs
1. It occurs in response to an external stimulus like touch, pressure or shock. 2. It is brought about by turgor changes in specific cells. 3. It is controlled by plant hormones.	1. It occurs voluntarily in response to our need and will. 2. It is brought about by contraction and relaxation of muscles. 3. It is controlled by cerebellum of the hind brain.

Q#24 Multiple Choice Questions:

i) Which of the following is a plant hormone?

a) Insulin b) thyroxine
c) oestrogen d) cytokinin

Ans. Cytokinin.

ii) The gap between two neurons is called a

a) dendrites b) synapse
c) axon d) impulse

Ans. Synapse

iii) The brain is responsible for

a) Thinking b) regulating the heart beat
c) Balancing the body d) all of these

Ans. All of these

Q#25 Which hormone is released into the blood when its sugar level rises? Name the organ which produces the hormone and its effect on blood sugar level. Also name one digestive enzyme that this organ secretes and the function of this enzyme.

Ans. Insulin hormone is released into the blood when its sugar level rises. Pancreas secretes the insulin hormone. The function of insulin hormone is to lower the blood sugar level. Deficiency of insulin hormone in the body causes a disease known as diabetes. Diabetes is characterized by large quantities of sugar in the blood. The insulin hormone controls the metabolism of sugar. If due to some reason, pancreas does not produce and secrete sufficient amount of insulin into blood, then the sugar level in the blood rises. The high sugar level in the blood can cause many harmful effects to the body of person. The people having severe diabetes are treated by giving injection of insulin.

The pancreas secretes pancreatic juice which contains enzymes like trypsin for digesting proteins, lipase for breakdown of emulsified fats and amylase for breakdown of starch.